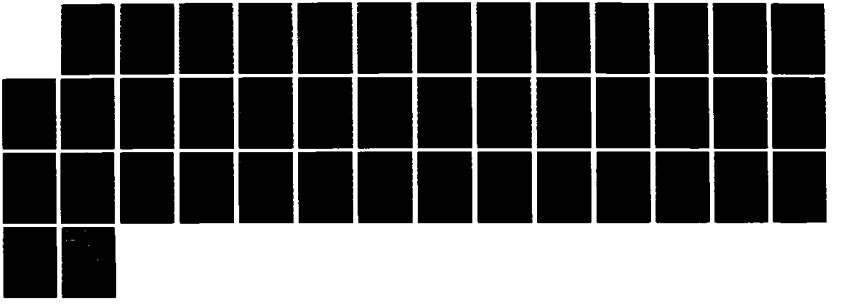
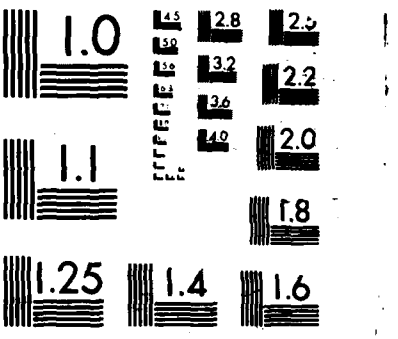
AD-A175 676 RESEARCHING URETHANE STRUCTURAL ADHESIVES(U) LITTLE (ARTHUR D) INC CAMBRIDGE MA P KOPF DEC 86 ADL-56950 DAAK70-83-D-0020 1/1

UNCLASSIFIED F/G 11/1 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.8
3.2
3.6
4.0

Report to
U.S. Army Belvoir Research
Development and
Engineering Center
DAAK70-83-D-0020
Task Order 0015
November 1986

Researching Urethane Structural Adhesives

Arthur D. Little, Inc.
Cambridge, MA 02140
Reference 56950

FINAL TECHNICAL REPORT
PHASE I: RESEARCHING URETHANE STRUCTURAL ADHESIVES

Prepared for
U.S. Army Belvoir Research, Development
and Engineering Center
Fort Belvoir, Virginia 22060-5606
DAAK70-83-D0020, Task Order 0015

by

Peter W. Kopf
Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140
56960-01
December 1986

Authorization for this research was contract No. DAAK70-83-D-0020, Task Order 0015, (Task order to a competitive contract awarded on a technical basis). The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

Sponsor: A. Rabalais, Program Planning Division,
Directorate for Advanced Systems Concepts
Belvoir Research Development and Engineering
Center

Foreword

This work was performed under the sponsorship of the U.S. Army, Belvoir Research, Development and Engineering Center. The work was performed by Arthur D. Little, Inc., of Cambridge, Massachusetts, under Task Order 0015 of contract DAAK70-83-D-0020.

Peter W. Kopf was the principal investigator. The work was performed under the technical direction of Mr. Brian Hornbeck, Bridge Division, Directorate for Combat Engineering, Belvoir Research, Development and Engineering Center. The contracting officer's representative was Mr. A. Rabalais, Program Planning Division, Directorate for Advance Systems Concepts, Belvoir Research, Development and Engineering Center.

Unclassified
CURITY CLASSIFICATION OF THIS PAGE

AD-A175 676

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS: N/A
2a. SECURITY CLASSIFICATION AUTHORITY: N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT: Unlimited Distribution
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): 56950	5. MONITORING ORGANIZATION REPORT NUMBER(S): DAAK70-83-D-0020, Task Order 0015
6a. NAME OF PERFORMING ORGANIZATION: Arthur D. Little, Inc. / 6b. OFFICE SYMBOL (If applicable): 75629	7a. NAME OF MONITORING ORGANIZATION: Directorate for Advanced Systems Concepts, Belvoir Research Development and Engineering Center
6c. ADDRESS (City, State and ZIP Code): 25 Acorn Park, Cambridge, MA 02140	7b. ADDRESS (City, State and ZIP Code): Fort Belvoir, VA 22060-5606
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: U.S. Army Belvoir RD&E Center / 8b. OFFICE SYMBOL (If applicable): STRBE-JBC	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: DAAK70-83-D-0020, Task Order 0015
8c. ADDRESS (City, State and ZIP Code): Ft. Belvoir, VA 22060-5606	10. SOURCE OF FUNDING NOS. — PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.
11. TITLE (Include Security Classification): Researching Urethane Structural Adhesives (U)	
12. PERSONAL AUTHOR(S): Peter Kopf	
13a. TYPE OF REPORT: Final / 13b. TIME COVERED: FROM 11/86 TO 12/86	14. DATE OF REPORT (Yr., Mo., Day): December 1986 / 15. PAGE COUNT: 37
16. SUPPLEMENTARY NOTATION	
17. COSATI CODES — FIELD / GROUP / SUB. GR.	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Structural Adhesives, Urethane

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

An on-line search of business and technical literature data bases was conducted as well as manual searches of adhesive supplier references. A listing was made of manufacturers of urethane adhesives and technical data studied to ascertain typical characteristics. A comparison of mechanical and chemical properties was carried out to identify the six most promising candidates. Recommendations were made for the evaluation and testing procedures to be used to characterize the performance of these adhesives.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Brian Hornbeck, U.S. Army, Belvoir RD&E Center	22b. TELEPHONE NUMBER (Include Area Code): (703) 664-5176 / 22c. OFFICE SYMBOL: STRBE-JBC

D FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

The U.S. Army requirements for bridging have become more rigorous in the past decade. The requirements have increased in load an span capability with the introduction of the M1 as the main battle tank. The bridges must remain transportable from site to site on tanks, trucks or trailers. The Army has gone to advanced materials for the construction of their bridges in order to meet these requirements. Epoxy-graphite fiber composites in combination with high strength aluminum are being developed as materials of construction for lightweight tactical bridging by the U.S. Army Belvoir Research, Development and Engineering Center. The construction and repair of these portable structures requires innovations in assembly technology since conventional riveting, bolting and welding are not as efficient as is required. The use of structural adhesives provides a bonding/fastening technology that can potentially meet the construction and repair requirements.

Several structural adhesives in the epoxy and acrylic chemical families have been evaluated for mobile bridge applications. Varying degrees of success have been obtained, but no adhesive system is totally satisfactory. An important class of structural adhesives, namely two-component urethanes, has not yet been investigated for its feasibility in this application. Urethanes are well established in application areas such as coatings and elastomers. They are now evolving into effective adhesive and sealant systems.

Urethanes are unique polymers with hard and soft segments synthesized into their molecular architecture. The mechanical properties of urethanes as a result can be varied over a much wider range than is possible with epoxy and acrylic systems. The viscoelastic nature of urethanes is an important attribute because it allows adhesive bonds to have better peel strength, impact resistance, and better adhesion to flexible substrates in comparison to epoxy and acrylic systems.

Therefore, a research program to evaluate two-component urethanes is recommended to determine their feasibility and usefulness a a structural adhesive. Since the bridges are fabricated from dissimilar materials, an adhesive with the properties of an urethane may be the solution.

1.2 Objectives

The objectives of this task order are to perform a technology assessment of urethane structural adhesives and as a result of this assessment determine which adhesives to select and acquire.

1.3 Tasks

Task I: Perform Technology Assessment and Interview with Suppliers

The first task is to perform a technology assessment for the application of urethane adhesives to similar situations. A discussion with suppliers of available urethane adhesives and urethane adhesives under development (C.1.a, b, c, d, e, f, g, h, j; C.2.a, b, c, d, e).

Task II: Selection/Acquisition of Adhesives

Systems selected will include the currently preferred epoxy adhesive as a control and up to six urethane adhesives. At least four of the urethane adhesives will be two-part ambient cure systems. A specific example of one of the urethane adhesives that will be included is p[illegible]p 6200 from Ashland which is currently used on [illegible] glass/polyester composites in the automotive area (C.1.a, b, c, d, e, f, g, h, j; C.2.a, b, c, d, e).

Task III: Documentation

Document the results of each subtask along with supporting data and analysis in a final technical report (C.1.i).

1.4 SUMMARY

The objectives of this project were to perform a technology assessment of Urethane Structural Adhesives and as a result of this assessment determine which adhesives to select and acquire. The first task was to perform a technology assessment for the application of urethane adhesives to similar situations. This was accomplished principally through discussions with suppliers of available commercial urethane adhesives, developmental urethane adhesives, and adhesive raw materials. In addition, an extensive study of the technical and commercial literature on urethane structural adhesives was conducted.

Initially a list of 40 domestic suppliers of urethane adhesives and/or urethane resin components was developed. The companies have all been contacted and wherever possible extensive discussions with their adhesive specialists carried out. Of these companies, approximately fourteen companies were found to manufacture urethane structural adhesives with properties potentially suitable for the applications of interest. A close examination of technical literature available from seven of these companies has resulted in the identification of six specific adhesives from five companies. Additional technical information will be available shortly and will be examined for any additional adhesive candidate. These will be added to the list and reported.

With the most promising urethane structural adhesives identified, the next phase of the study may be initiated. In this phase the adhesives are evaluated for tensile strength and adhesive strength under a variety of environmental conditions using tests and procedures approved by the Belvoir Research and Development Center.

2.0 RESULTS

2.1 Technology Assessment

The first task in the program was to identify suppliers of urethane adhesives. This was done employing adhesive supplier directories as well as Arthur D. Little's knowledge of the adhesive industry. An initial list was generated of 40 companies which supply urethane adhesives or urethane resin components. These companies were contacted and wherever possible extensive discussions with adhesive technical service personnel carried out. The following is a list of the companies and a brief statement of the results.

COMPANIES CONTACTED

1. ARCO CHEMICAL CO.
   Specialty Chemicals
   Marshall Building
   Westown Road at Westchester Pike
   Westchester, PA 91382

   No urethane adhesive product line. Makes only polyol and polyamine precursors. Suggested adhesive manufacturer.

2. ASHLAND CHEMICAL CO.
   1745 Cottage Street
   Ashland, OH 44805

   Providing literature on their Pliogrip structural urethane adhesive systems.

3. B.F. GOODRICH CORP.
   500 South Main Street
   Akron, OH 44318

   Providing literature on their one structural urethane adhesive (PL-550).

4. BOSTIK CO.
   Boston Street
   Middleton, MA 01949

   Providing literature on their Supergrip 2000 urethane adhesive line.

5. CHEMICAL COMPONENTS, INC.
20 DeForest Avenue
East Hanover, NJ 07936

No urethane adhesive product line.

6. CHRYSLER, INC.
5437 West Jefferson
Trenton, MI 48413

No urethane adhesive product line.

7. PETER COOPER
7401-T Carmel Executive Park
Charlotte, NC 28226

Company was sold to Swift Adhesives.

8. AMERICAN CYANAMID CO.
One Cyanamid Plaza
Wayne, NJ 07470

Providing literature on their Cybond urethane adhesive line.

9. DEVCON CORP.
30 Endicott Street
Danvers, MA 01923

Providing literature on their Flexane urethane adhesive line.

10. DOW CHEMICAL CO.
1603 Building
Midland, MI 48674

No urethane adhesive product line. Supplies resin components.

11. EMERSON AND CUMING, DIV. W.R. GRACE, INC.
77 Dragon Court
Woburn, MA 01888

Providing literature on their Eccothane urethane adhesive line.

12. ESSEX CHEMICAL CO.
1401 Broad Street
Clifton, NJ 07015

Providing literature on their Betamate urethane adhesive line.

13. FIELCO CHEMICAL CORP.
1957 Pioneer Road
Huntington Valley, PA 19006

No urethane adhesive product line.

14. H.B. FULLER CORP.
40 Hayes Memorial Drive
Marlborough, MA 01752

Providing literature on their appropriate urethane adhesives.

15. FURANE CORP.
5121 San Fernando Road, West
Los Angeles, CA 90039

Providing literature on their #5767 and #5768 urethane adhesives.

16. GENERAL TIRE AND RUBBER CO.
One General Street
Akron, OH 44329

No urethane adhesive product line.

17. GOODYEAR TIRE AND RUBBER CO.
Industrial Products Division
215 First Avenue
Needham Heights, MA 02194

Their adhesives operation has been sold to Ashland. Referred inquiry to Ashland Chemical Corp.

18. HENKEL CORP.
2010 East Hennepin Avenue
Minneapolis, MN 55413

No urethane adhesive product line. Supplies acrylic polyol resins.

19. HERNON MANUFACTURING, INC.
865 Essex Street
Brooklyn, NY 11208

No urethane adhesive product line.

20. HYSOL, DIV. OF THE DEXTER CORP.
2850 Willow Pass Road
Pittsburg, CA 94565

Providing literature on their one structural urethane adhesive (EA 9525).

21. LOCTITE CORP.
705 North Mountain Road
Newington, CT 06111

No urethane adhesive product line.

22. LORD CORP.
Industrial Adhesives Division
2000 West Grandview Boulevard
P.O. Box 10038
Erie, PA 16514

Providing literature on their Tyrite urethane adhesives line.

23. METHODS RESEARCH PRODUCTS, INC.
P.O. Box 1367
North Wales, PA 19454

No urethane adhesive product line.

24. MOBAY CORP.
Mobay Road
Pittsburgh, PA 15205

Component manufacturer for urethane adhesives only. Recommended several urethane adhesives manufacturers.

25. MONSANTO CHEMICAL CORP.
703 Worcester Street
Springfield, MA 01151

No urethane adhesive product line.

26. MORTON-THIOKOL
1275 Lake Avenue
Woodstock, IL 60098

Providing literature on appropriate urethane adhesives.

27. POLYURETHANE CORPORATION OF AMERICA
P.O. Box 8
Everett, MA 02149

Providing literature on their appropriate urethane adhesives. Manufacturers of urethane adhesives to specifications.

28. K.J. QUINN CO.
195 Canal Street
Malden, MA 02148

Providing literature on their urethane adhesive line.

29. ROHM & HAAS CO.
399 Thornall Street
Edison, NJ 08837

No urethane adhesives product line.

30. RUCO POLYMER CORP., DIV. OCCIDENTAL PETROLEUM
New South Road
Hicksville, NY 11802

Providing literature on their urethane adhesive line.

31. JOHN SHELLEY CO. (Distributor)
16 Mica Lane
Wellesley Hills, MA 02181

Providing literature on 3M structural urethane adhesives. Refer to 3M.

32. SWIFT ADHESIVE CO.
9724 Industrial Drive
Pineville, NC 28134

Providing literature on their urethane adhesives line.

33. SYNTHETIC SURFACES, INC.
P.O. Box 241
South Plains, NJ 07076

Providing literature on their urethane adhesives line.

34. TEXACO CHEMICAL CO.
4800 Fournace Place
Bellaire, TX 77401

No urethane adhesive product line. Supplies polyol and polyamine intermediate.

35. 3M
Adhesives, Coatings and Sealers Division
3M Center
St. Paul, MN 55144

Providing literature on three structural urethane adhesives (3532, 3535, 3549).

36. TRA-CON ADHESIVES CO.
55 North Street
Medford, MA 02155

No urethane adhesive product line.

37. UNION CARBIDE CORP.
39 Old Ridgeberry Road
Danbury, CT 06817

No urethane adhesive product line. Component manufacturer for urethane adhesives.

38. UNIROYAL CORP.
Spencer Street
112-2 TSSC Building
Naugatuck, CT 06770

No urethane adhesive product line.

39. UPACO ADHESIVES, INC.
3 East Spit Brook Road
Nashua, NH 03060

Providing literature on their urethane adhesives line.

40. UPJOHN CORP.
P.O. Box 685
La Porte, TX 77571

Company has been sold to Dow.

2.2 Selection/Acquisition of Adhesives

Nineteen companies have indicated that they manufacture structural urethane adhesives which have potential use in this particular application. As of this time, the information from 17 of these companies has been received and is summarized below. Information from the remainder of these companies is expected shortly.

1. American Cyanamid Co.

Cyanamid's urethane adhesives products have been discontinued.

2. Ashland Chemical Co.

A. Pliogrip 6600

- Two-part, 100% reactive urethane structural adhesive.
- Bonds engineered plastics, metals.

Viscosity - 27,000 (#6 @ 10RPM)
Tensile - 2,500 psi
Elongation - 60-70%
Lap shears (alum.) - 2,200 psi @ room temperature
(primed alum.) - 2,500 psi @ room temperature
Shelf life - 6 months
Gel time - 1-10 minutes (dep. on curative)
Handling time - 12 minutes @ 60°F

B. *Pliogrip 6000*

- Two-part, 100% reactive structural urethane adhesive.
- Bonds plastics and metals.

Viscosity - 27,000 cps
Gel time - 2-15 minutes (dep. on curative)
Tensile - 2,400 psi
Elongation - 52%
Shelf life - 6 months

Note: The main difference between Pliogrip 6600 and 6000 is that 6600 has a slightly stronger bond strength.

3. Bostik Co.

A. Supergrip 9601

- Solventless urethane adhesive.
- Solid, one-part moisture cure.
- Outstanding hydrolytic and chemical resistance.
- No heat cure required.
- Bonds most plastics and metals.
- Flexible adhesive film.

Viscosity - 55,000 cps @ 140°F
Water resistance - excellent
Cured film tensile - 3,000 lbs
Heat resistance - 93-121°C
Elongation - 550%

B. Supergrip 9701

- Solventless urethane adhesive.
- One-part, moisture-cure, rapid setting, no heat.
- Bonds most plastics and metals.

Viscosity - 27,000 cps @ 75°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 4,100 lbs
Elongation - 660%

C. Supergrip 9702

- o Solventless urethane adhesive.
- o Solid, moisture curing with delayed setting characteristics, no heat.
- o Bonds most plastics and metals.

Viscosity - 55,000 @ 140°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 2,600 lbs
Elongation - 500%

D. Supergrip 9704

- o Solventless urethane adhesive.
- o Solid, one-part, moisture-cure with rapid setting characteristics, no heat.
- o Bonds most plastics and metals.

Viscosity - 70,000 @ 167°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 4,100 lbs
Cured film elongation - 660%

E. Supergrip 9705

- o High viscosity solid, one-part moisture cure with rapid setting characteristics, no heat.
- o Bonds most plastics and metals.
- o Solventless urethane adhesives.

Viscosity - 250,000 @ 212°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 4,100 lbs
Cured film elongation - 650%

4. Devcon Corp.

Devcon's Flexane line of urethane adhesives does not provide the properties required.

5. Emerson & Cuming, Div. of W.R. Grace, Inc.

Two-component systems.

A. Eccothane 7541

Very hard, rigid, low cost system. Good high temperature capabilities.

- Tensile - 7,000 psi
- Elongation - 13%
- Pot life - 40 mins
- Cure - 24 hrs @ 25°C
- Viscosity - 6,000 cps @ 25°C
- Gel time - 3 hrs
- Coefficient of thermal exp. - 71 x 10^{-6} /°C
- Service temperature - -30 to 125°C

B. Eccothane 7031

Super high impact, crystal clear system that is highly resistance to yellowing, ozone and UV attack.

- Tensile - 4,800 psi
- Elongation - 25%
- Pot life - 30 mins
- Cure - 24 hrs @ 25°C
- Viscosity - 3,000 cps @ 25°C
- Gel time - 2 hrs
- Coefficient of thermal exp. - 105 x 10^{-6} /°C
- Service temperature - -30 to 125°C

C. Eccothane CPC-18

- Tensile - 2,800 psi
- Elongation - 300%
- Pot life - 30 mins
- Cure - 24 hrs @ 25°C
- Viscosity - 55,000 cps @ 25°C
- Gel time - 2 hrs
- Coefficient of thermal exp. - 221 x 10^{-6} /°C
- Service temperature - -68 to 149°C

D. Eccothane CPC-19

- Tensile - 2,400 psi
- Elongation - 450%
- Pot life - 30 mins
- Cure - 24 hrs @ 25°C
- Viscosity - 24,000 cps @ 25°C
- Gel time - 3 hrs
- Coefficient of thermal exp. - 282 x 10^{-6} /°C
- Service temperature - -68 to 149°C

E. Eccothane CPC-41

- Tensile - 2,000 psi
- Elongation - 150%
- Pot life - 30 mins
- Cure - 24 hrs @ 25°C
- Viscosity - 8,000 cps @ 25°C
- Gel time - 4 hrs
- Coefficient of thermal exp. - 217 x 10^{-6}
- Service temperature - -70 to 105°F

F. Eccothane CPC-39

- Tensile - 1,500 psi
- Elongation - 300%
- Pot life - 30 mins
- Cure - 8 hrs @ 66°C
- Viscosity - 6,800 cps @ 25°C
- Gel time - N.A.
- Coefficient of thermal exp. - 200 x 10^{-6} /°C
- Service temperature - -57 to 121°C

6. Essex Chemical Co.

Betamate 57.541/57.542

- Two-part, ambient cure, non-sagging adhesive.
- Tough elastomeric character, provides noise and vibration dampening to a structure.

Viscosity - 30-35,000 cps (RVF #6 @ 4 rpm @ 77°F)
Work life - 6-8 minutes
Shelf life - 6 months
Shear strength (alum.) - 1500-2000 psi
(FRP) - 600-1000 psi

7. H.B. Fuller

A. UR - 1100

- One-component, heat-cured.
- Bonds plastics and metals.
- Good heat resistance.

Viscosity - 120,000 cps
Cure rate - 15 minutes @ 260°F
Tensile strength - 4,186 psi @ -67°F
- 3,957 psi @ 77°F
- 1,518 psi @ 180°F

B. UR - 2139

- Two-component system for plastics and metals.
- Good sag and acid resistance.

Viscosity - 25,000 cps
Pot life - 45-75 minutes
Cure rate - 30 days @ 77°F or 4-5 hours @ 140°F
Tensile strength - 4,780 psi @ -67°F
- 1,400 psi @ 77°F
Coefficient of thermal expansion - $7.4 \times 10^{-5}/°F$

C. UR - 2183

- o Fast-cure, two-component system
- o A polyester urethane for bonding plastics

Viscosity - 7,500
Pot life - 10-15 minutes
Cure rate - 3-5 days @ 77°F or 2-3 hours @ 150°F
Shelf life - 6 months
Hardness (Shore A) - 92 ± 8

D. UR - 2170

- o Two-component system with good chemical resistance.
- o Bonds metals and plastics.
- o Good moisture resistance and dry heat aging.

Viscosity - 37,000 cps
Pot life - 30 minutes
Cure rate - 5-7 days @ 77°F or 1-2 hours @ 158°F
Shelf life - 6 months

Note: More detailed product data on all H.B. Fuller urethanes is currently being compiled.

8. Furane Corp.

A. Uralane 5738 A/B

- Moisture resistant.
- Does not craze most plastics.

Consistency - semi-paste
Pot life - 15 minutes
Cure rate - 20 hours @ 77°F and 4 hours @ 150°F
Upper operating temperature - 150°F
Lap shear strength (alum.) - 2,450 psi @ -67°F
- 2,000 psi @ 77°F
- 380 psi @ 180°F
Lap shear strength (epoxy) - approx. 800 psi @ 77°F
Weathering - good

B. Uralane 5767 A/B

- High temperature adhesive.
- Bonds various metal substrates.

Consistency - semi-paste
Pot life - 15 minutes
Cure rate - 2 hours @ 77°F and 16 hours @ 150°F
Upper operating temperature - 270°F
Lap shear strength (alum.) - 3,000 psi @ -67°F
- 1,700 psi @ 77°F
- 700 psi @ 250°F
Lap shear strength (epoxy) - approx. 800 psi @ 77°F
Weathering - good

C. Uralane 5768 A/B

- o Bonds plastics and metals.
- o Somewhat higher bond strengths than 5767 A/B.

Consistency - semi-paste
Pot life - 30 minutes
Cure rate - 16 hours @ 150°F or 7 days @ 75°F
Upper operating temperature - 250°F
Lap shear strength (alum.) - 3,000 psi @ -67°F
- 1,800 psi @ 77°F
- 700 psi @ 250°F
Lap shear strength (epoxy) - approx. 900 psi
Weathering - good

D. Uralane 88800 A/B

- o Quick set, non-flow adhesive.
- o Used to bond interior aircraft parts.

Consistency - paste
Pot life - 1 minute
Cure rate - 24 hours @ 77°F
Upper operating temperature - 175°F
Lap shear strength (alum.) - 3,400 psi @ -67°F
- 1,200 psi @ 77°F
- 800 psi @ 180°F
Weathering - good

9. B.F. Goodrich Corp.

PL-550

Viscosity - Part A 50-70,000 cps
Part B 1,000 cps
Pot life - 15-30 minutes
Handling time - 2 hours
Full cure @ room temperature - 7 days
Service temperatures - -20°F to 160°F
Weatherability - good
Tensile - 2,000 psi (with room temperature cure)
- 2,800 psi (with room temperautre cure and post bake)
Elongation - 50%
Lap shear strength (alum.) - 1,200 psi (with room temperature cure)
- 2,000 (with room temperature cure and post cure)

10. Hysol, Division of the Dexter Corp.

EA-9525

- Two-component urethane with wide service temperature.
- Bonds plastics and dissimilar materials.

Viscosity (mixed) - 10,000 cps @ 77°F
Pot life - 15 mins.
Cure time - 10 days @ 77°F or 1 hr @ 77°F plus 1 hr @ 250°F
Service temperature - -100°F to +300°F

Tensile strength - 7,000 psi
Elongation - 275%
Shear strength (alum.) - 3,000 psi

11. Lord Corp.

A. Tyrite 7500

- Two-part structural urethane for plastics and metals.
- Room T cure or heat accelerated.
- Flexible, non-sagging, 100% solids.

Pot life - 6-10 mins
Handling strength - 2 hrs @ 75°F
Impact resistance - -30°F to 240°F
Viscosity - 500,000 @ 25°C
Lap shear (alum.) - 2130 psi (COH) Room T
- 1540 psi (COH) 2 wks @ 100°F & 100% R.H.
- 1640 psi (COH) 2 wks salt spray

Lap shear (lexan) - 1140 psi (COH) Room T
- 1150 psi (COH) 2 wks @ 100°F & 100% R.H.
- 1130 psi (COH) 2 wks salt spray

Shelf life - 6 months

B. Tyrite 7520

- Two-part structural urethane for plastics and metals.
- 100% solids, room temperature cure, fast cure.
- Semi-rigid, non-sagging, good impact strength.

Pot life - 7 mins
Handling strength - 40 mins
Viscosity - 15,000 cps
Full cure - 24 hrs
Lap shear (alum.) - 1500 psi (COH) 2 hrs @ Room T
- 1900 psi (COH) 1 wk @ Room T
- 1300 psi (COH) 1 wk salt spray
Lap shear (ABS) - 500 psi (COH) 2 hrs @ Room T
- 480 psi (COH) 1 wk @ Room T
- 540 psi (COH) 1 wk salt spray
Shelf life - 6 months

C. Tyrite 7602

- Single pack moisture cure.
- Bonds metals and plastics.
- Semi-flexible, good chemical resistance, non-sagging.

Handling strength - 4-6 hrs
Viscosity - 310,000 cps
Full cure - 5-10 days (R.H. dependent)
Tensile (alum.) - 479 psi (COH) 48 hrs
- 741 psi (COH) 96 hrs
(FRP) - 506 psi (COH) 48 hrs
- 651 psi (COH) 96 hrs
Shelf life - 6 months

12. Morton-Thiokol

Morton-Thiokol's urethane adhesives do not provide the properties required.

13. 3M Corp.

A. EC-3549

- Two-component, room temperature cure.
- Impact resistant structural adhesive.
- Excellent adhesion to many primed or painted metals and various plastic substrates.
- Use Primer EC 1945 B/A (or Corogard 9) for maximum resistance to water, humidity and salt spray environments.

Viscosity - 22,500 cps (#4 Spindle, 10 RPM)
Work life - 60 mins @ 72°F
Shear strength - 1170 psi (48 hrs) plastic to steel
- 1400 psi (48 hrs) steel to steel
Pot life - 8 hrs

B. EC 3532

- Two-component room temperature cure.
- Tough impact resistant
- Excellent adhesion to many primed or painted metals and various plastic substrates.
- Use 3M Primer EC-1945 B/A or Corogard 9 for metals.

Viscosity - 22,500 cps (#4 Spindle, 10 RPM)
Work life - 9 mins @ 65°F

Shear strength - 2190 psi (72 hrs @ 75°F) alum. to alum.
- 1130 psi (72 hrs @ 75°F) phenolic laminate
Tensile - 3000 psi (1 hr @ 250°F, 30 mins @ 285°F) (ASTM D-738)
Elongation - 96%
Pot life - 8 hrs

C. EC 3535

- Two-component urethane which cures at room temperature or with heat.
- Water, humidity, salt spray, and impact resistant.
- Bonds primed or painted metals and various plastics.

Viscosity - 22,500 cps
Work life - 1-4 minutes
Shear strength (alum.) ~ 2,000 psi @ 75°F
(epoxy) ~ 1,500 psi @ 75°F
Tensile - 3,000 psi
Elongation - 96%
Pot life - 8 hours

Note: The main difference in the 3M urethanes is cure time and work life.

14. Polyurethane Corporation of America

Polyurethane Corp.'s urethane adhesives do not provide the properties required.

15. K.J. Quinn Co.

Quinn's urethane adhesives do not provide the properties required.

16. Ruco Polymer Corp.

Ruco's urethane adhesives do not provide the properties required.

17. Swift Adhesives

Swift's urethane adhesive line does not provide the properties required.

18. Synthetic Surfaces, Inc.

Synthetic Surfaces' urethane adhesives do not provide the properties required.

19. Upaco Adhesives, Inc.

Upaco's urethane adhesives do not provide the properties required.

MANUFACTURERS' TECHNICAL DATA ON URETHANE ADHESIVES

Company Product/Property	Room Temp. Viscosity (cps)	Room Temp. Work Life	Full Cure[1] @ Room Temp.	Tensile Strength (psi)	Elongation (%)	Lap Shear Strength (Alum./Epoxy) (psi)	Service Temperature Range (°F)	Weatherability
ASHLAND								
Pliogrip 6600	27,000	8-10 mins.	24-48 hrs. or 20-30 mins. @ 250°F	2,500	60-70	2,200/N.A.	-60 to 180	Very Good
BOSTIK								
Supergrip 9701	10,000 @ 100°C[2]	<1 min.*	24-48 hrs.*	4,100	660	700*/N.A.	Up to 160	Good to Very Good
Supergrip 9704	50,000 @ 100°C[2]	<1 min.*	24-48 hrs.*	4,100	660	700*/N.A.	Up to 160	Good to Very Good
Supergrip 9705	250,000 @ 100°C[2]	<1 min.*	24-48 hrs.*	4,100	650	700*/N.A.	Up to 160	Good to Very Good
Supergrip 9601	11,000 @ 100°C[2]	<1 min.*	24-48 hrs.*	3,000	550	700*/N.A.	Up to 160	Good to Very Good
EMERSON & CUMING								
Eccothane 7541	6,000	3 mins.	24 hrs.	7,000	13	N.A.	-22 to 250	N.A.
Eccothane 7031	3,000	2 mins.	24 hrs.	4,800	25	N.A.	-22 to 250	N.A.
Eccothane CPC-18	55,000	2 mins.	24 hrs.	2,800	300	N.A.	-90 to 235	N.A.
Eccothane CPC-19	24,000	3 mins.	24 hrs.	2,400	450	N.A.	-90 to 235	N.A.
Eccothane CPC-41	8,000	4 mins.	24 hrs.	2,000	150	N.A.	-95 to 220	N.A.
ESSEX								
57.541/57.542	30-35,000	6-8 mins.	24 hrs.*	2,000*	5*	1,500-2,000/ 600-1,000	Up to 180	Very Good

MANUFACTURERS' TECHNICAL DATA ON URETHANE ADHESIVES (Continued)

Company Product/Property	Room Temp. Viscosity (cps)	Room Temp. Work Life	Full Cure[1] @ Room Temp.	Tensile Strength (psi)	Elongation (%)	Lap Shear Strength (Alum./Epoxy) (psi)	Service Temperature Range (°F)	Weatherability
FURANE								
Uralane 5738A/B	Semi-paste	15 mins.	20 hrs. @ 77°F[3] & 4 hrs. @ 150°F	N.A.[4]	N.A.	2,000/800*	<150	Good
Uralane 5767A/B	Semi-paste	15 mins.	2 hrs. @ 77°F[3] & 16 hrs. @ 150°F	N.A.[4]	N.A.	1,700/800*	<270	Good
Uralane 5768A/B	Semi-paste	30 mins.	7 days or 16 hrs. @ 150°F	N.A.[4]	N.A.	1,800/900*	<250	Good
Uralane 88800A/B	Paste	1 min.	24 hrs.	N.A.[4]	N.A.	1,200/N.A.	<175	Good
B.F. GOODRICH								
PL-550	50-70,000	15 mins.	7 days	2,000	50	1,200/N.A.	-20 to 160	Good
HYSOL								
EA-9525	10,000	15 mins.	10 days or 1 hr. @ R.T. & 1 hr. @ 250°F	7,000	275	3,000/800*	-100 to 300	Good
LORD								
Tyrite 7500	500,000	6 mins.	24 hrs.* or 15 mins. @ 240°F	1,000*	80-100*	2,130/1,000*	Up to 200	Good
Tyrite 7520	15,000	7 mins.	24 hrs.	2,000*	N.A.	1,900/500*	Up to 200	Good

MANUFACTURERS' TECHNICAL DATA ON URETHANE ADHESIVES (Continued)

Company Product/Property	Room Temp. Viscosity (cps)	Room Temp. Work Life	Full Cure[1] @ Room Temp.	Tensile Strength (psi)	Elongation (%)	Lap Shear Strength (Alum./Epoxy) (psi)	Service Temperature Range (°F)	Weatherability
3M								
EC-3532	22,500	5-15 mins.	24 hrs.	3,000	96	2,000/1,500*	Up to 180	Very Good
EC-3535	22,500	45-240 secs.	24 hrs.	3,000	96	2,000/1,500*	Up to 180	Very Good
EC-3549	22,500	40-70 mins.	7 days	3,000	96	2,000/1,500*	Up to 180	Very Good

---

N.A. - Not available.

*Approximate value.

[1] Many cure much faster with heat.

[2] Hot melt-type urethane, adhesive is applied at 100°C.

[3] Heat is required for cure.

[4] Tensile value will be higher than lap shear value.

3.0 CONCLUSIONS

The following six urethane adhesives ~~have been~~ determined to possess the most interesting and desirable properties for use in this application. When all information is received, a modified list of preferred adhesives will be prepared describing their most important characteristics.

1. Ashland - Pliogrip 6600

Pliogrip 6600, a two-component system, has been selected as a result of its rapid setting ability and proven use in bonding automotive composites.

2. Emerson and Cuming - EC 7541

Although the cure rate is somewhat slow, this two-component system possesses a very high tensile strength (7000 psi).

3. Emerson and Cuming - EC 7031

EC 7031, also a two-part system, shows very good environmental resistance and tensile strength (4800 psi).

4. Furane-Uralane 5738 A/B

A two-part semi-paste with good tensile and lap shear strength, also has suitable weatherability.

5. Hysol EA-9525

A two-part ambient cure system with exceptionally high tensile strength and good lap shear strength. Excellent low temperature properties.

6. 3M - EC 3532

EC 3532 is a two-component system which has excellent impact resistance and bonds especially well to primed metals and plastics.

4.0 RECOMMENDATIONS

The technology assessment and identification carried out in Phase I, demonstrates that viable urethane structural adhesives are commercially available. These adhesives should be evaluated in a test program designed to measure their performance over a range of environmental conditions and in comparison with the most suitable acrylic and epoxy adhesives identified to date. The test evaluations should include (1) lap shear bond strength evaluation, (2) environmental testing of cast systems (such as the Mecklenburg Stress Relaxation Test), and (3) torsional bond strength evaluation (such as described by Lin and Bell).

At the conclusion of this experimental program, it should be possible to identify the best structural adhesive system for use in the construction and repair composite containing mobile bridging systems.

END

2-87

DTIC